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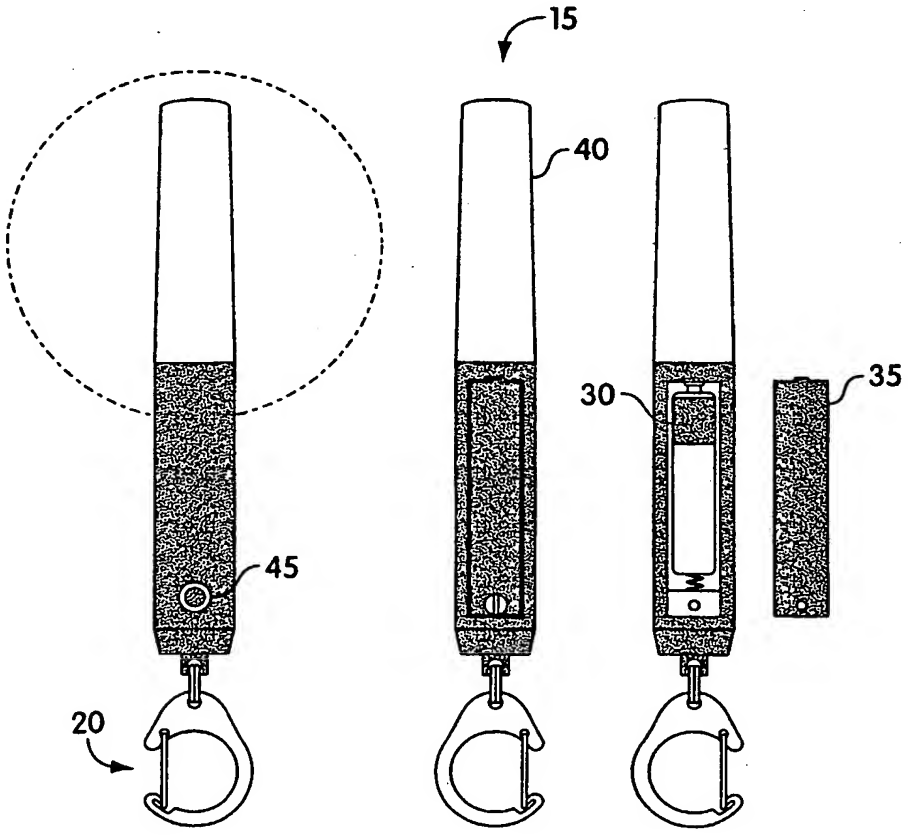
(54) Title: LIGHT-EMITTING DIODE BASED PRODUCTS



(57) Abstract: High-brightness LEDs, combined with a processor for control, can produce a variety of pleasing effects for display and illumination. A system disclosed herein uses high-brightness, processor-controlled LEDs in combination with diffuse materials to produce color-changing effects. The systems described herein may be usefully employed to bring autonomous color-changing ability and effects to a variety of consumer products and other household items. The system may also include sensors so that the illumination of the LEDs might change in response to environmental conditions or a user input. Additionally, the system may include an interface to a network, so that the illumination of the LEDs may be controlled via the network.

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LIGHT-EMITTING DIODE BASED PRODUCTS

Cross Reference to Related Applications

This application claims the benefit of, and incorporates by reference, the entire disclosure of the following pending United States provisional patent applications:

U.S. Provisional Patent App. No. 60/199,333, filed April 24, 2000; and

U.S. Provisional Patent App. No. 60/211,417, filed June 14, 2000.

This application is a continuation-in-part of, claims priority to, and incorporates by reference the entire disclosure of the following pending United States patent applications:

U.S. Patent App. No. 09/215,624, filed Dec. 17, 1998;

U.S. Patent App. No. 09/213,607, filed Dec. 17, 1998;

U.S. Patent App. No. 09/213,189, filed Dec. 17, 1998;

U.S. Patent App. No. 09/213,581, filed Dec. 17, 1998;

U.S. Patent App. No. 09/213,540, filed Dec. 17, 1998;

U.S. Patent App. No. 09/333,739, filed Jun. 15, 1999;

U.S. Patent App. No. 09/344,699, filed Jun. 25, 1999;

U.S. Patent App. No. 09/626,905, filed Jul. 27, 2000;

U.S. Patent App. No. 09/669,121, filed Sept. 25, 2000; and

U.S. Patent App. No. 09/742,017, filed Dec. 20, 2000.

devices are often lit to provide enhanced decorative effects. United States Patents 6,086,222 and 5,975,717, for example, disclose lighted ornamental icicles with cascading lighted effects. As a significant disadvantage, these systems employ complicated wiring harnesses to achieve dynamic lighting. Other examples of crude dynamic lighting may be found in consumer products ranging from consumer electronics to home illumination (such as night lights) to toys to clothing, and so on.

Thus, there remains a need for existing products to incorporate programmable, multi-colored lighting systems to enhance user experience with sophisticated color changing effects, including systems that operate autonomously and systems that are associated with wired or wireless computer networks.

Summary Of The Invention

High-brightness LEDs, combined with a processor for control, can produce a variety of pleasing effects for display and illumination. A system disclosed herein uses high-brightness, processor-controlled LEDs in combination with diffuse materials to produce color-changing effects. The systems described herein may be usefully employed to bring autonomous color-changing ability and effects to a variety of consumer products and other household items. The system may also include sensors so that the illumination of the LEDs might change in response to environmental conditions or a user input. Additionally, the system may include an interface to a network, so that the illumination of the LEDs may be controlled via the network.

Fig. 15 shows a light according to the principles of the invention.

Fig. 16 shows a lighting system according to the principles of the invention.

Fig. 17 shows a light according to the principles of the invention.

Fig 18 shows a light and reflector arrangement according to the principles of the invention.

Fig. 19 shows a light and reflector arrangement according to the principles of the invention.

Fig. 20 shows a light and reflector arrangement according to the principles of the invention.

Fig. 21 shows a light and reflector arrangement according to the principles of the invention.

Fig. 22 is a block diagram of an embodiment of a device according to the principles of the invention having internal illumination circuitry;

Fig. 23 is a block diagram of an embodiment of a device according to the principles of the invention having external illumination circuitry;

Fig. 24 depicts an autonomous color-changing shoe according to the principles of the invention;

Fig. 25 depicts a device for use with color-changing icicles;

Figs. 26-30 depict color-changing icicles; and

Fig. 31 depicts a color-changing rope light.

luminescent lamps, light emitting diodes, and cathode luminescent sources using electronic satiation, as well as miscellaneous luminescent sources including galvano-luminescent sources, crystallo-luminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources, sonoluminescent sources, and radioluminescent sources. Illumination sources may also include luminescent polymers capable of producing primary colors.

The term "illuminate" should be understood to refer to the production of a frequency of radiation by an illumination source with the intent to illuminate a space, environment, material, object, or other subject. The term "color" should be understood to refer to any frequency of radiation, or combination of different frequencies, within the visible light spectrum. The term "color," as used herein, should also be understood to encompass frequencies in the infrared and ultraviolet areas of the spectrum, and in other areas of the electromagnetic spectrum where illumination sources may generate radiation.

Figure 1 is a block diagram of a device according to the principles of the invention. The device may include a user interface 1, a processor 2, one or more controllers 3, one or more LEDs 4, and a memory 6. In general, the processor 2 may execute a program stored in the memory 6 to generate signals that control stimulation of the LEDs 4. The signals may be converted by the controllers 3 into a form suitable for driving the LEDs 4, which may include controlling the current, amplitude, duration, or waveform of the signals impressed on the LEDs 4.

As used herein, the term processor may refer to any system for processing electronic signals. A processor may include a microprocessor, microcontroller, programmable digital signal processor or other programmable device, along with external memory such as read-only memory, programmable read-only memory, electronically erasable programmable read-only memory, random access memory, dynamic random access memory, double data

number of outputs. By controlling the LEDs 4 independently, color mixing can be applied for the creation of lighting effects.

The memory 6 may store algorithms or control programs for controlling the LEDs 4. The memory 6 may also store look-up tables, calibration data, or other values associated with the control signals. The memory 6 may be a read-only memory, programmable memory, programmable read-only memory, electronically erasable programmable read-only memory, random access memory, dynamic random access memory, double data rate random access memory, Rambus direct random access memory, flash memory, or any other volatile or non-volatile memory for storing program instructions, program data, address information, and program output or other intermediate or final results. A program, for example, may store control signals to operate several different colored LEDs 4.

A user interface 1 may also be associated with the processor 2. The user interface 1 may be used to select a program from the memory 6, modify a program from the memory 6, modify a program parameter from the memory 6, select an external signal for control of the LEDs 4, initiate a program, or provide other user interface solutions. Several methods of color mixing and pulse width modulation control are disclosed in U.S. Patent 6,016,038 "Multicolored LED Lighting Method and Apparatus", the teachings of which are incorporated by reference herein. The processor 2 can also be addressable to receive programming signals addressed to it.

The '038 patent discloses LED control through a technique known as Pulse-Width Modulation (PWM). This technique can provide, through pulses of varying width, a way to control the intensity of the LED's as seen by the eye. Other techniques are also available for controlling the brightness of LED's and may be used with the invention. By mixing several hues of LED's, many colors can be produced that span a wide gamut of the visible spectrum. Additionally, by varying the relative intensity of LED's over time, a variety of

A fourth mode 11 may be accessed from the third mode 10. In the fourth mode 11, the device may strobe, that is, flash on and off. The parameter may correspond to the color of the strobe or the rate of the strobe. At a certain value, the parameter may correspond to other lighting effects, such as a strobe that alternates red, white, and blue, or a strobe that alternates green and red. Other modes, or parameters within a mode, may correspond to color changing effects coordinated with a specific time of the year or an event such as Valentine's Day, St. Patrick's Day, Easter, the Fourth of July, Halloween, Thanksgiving, Christmas, Hanukkah, New Years or any other time, event, brand, logo, or symbol.

A fifth mode 12 may be accessed from the fourth mode 11. The fifth mode 12 may correspond to a power-off state. In the fifth mode 12, no parameter may be provided. A next transition may be to the first mode 8, or to some other mode. It will be appreciated that other lighting effects are known, and may be realized as modes or states that may be used with a device according to the principles of the invention.

A number of user interfaces may be provided for use with the device. Where, for example, a two-button interface is provided, a first button may be used to transition from mode to mode, while a second button may be used to control selection of a parameter within a mode. In this configuration, the second button may be held in a closed position, with a parameter changing incrementally until the button is released. The second button may be held, and a time that the button is held (until released) may be captured by the device, with this time being used to change the parameter. Or the parameter may change once each time that the second button is held and released. Some combination of these techniques may be used for different modes. For example, it will be appreciated that a mode having a large number of parameter values, such as a million or more different colors available through color changing LEDs, individually selecting each parameter value may be unduly cumbersome, and an approach permitting a user to quickly cycle through parameter

In one embodiment, a mode may have a plurality of associated parameters, each parameter having a parameter value. For example, in a color-changing strobe effect, a first parameter may correspond to a strobe rate, and a second parameter may correspond to a rate of color change. A device having multiple parameters for one or more modes may have a number of corresponding controls in the user interface.

The user interface may include user input devices, such as the buttons and adjustable controls noted above, that produce a signal or voltage to be read by the processor. They voltage may be a digital signal corresponding to a high and a low digital state. If the voltage is in the form of an analog voltage, an analog to digital converter (A/D) may be used to convert the voltage into a processor-useable digital form. The output from the A/D would then supply the processor with a digital signal. This may be useful for supplying signals to the lighting device through sensors, transducers, networks or from other signal generators.

The device may track time on an hourly, daily, weekly, monthly, or annual basis. Using an internal clock for this purpose, lighting effects may be realized on a timely basis for various Holidays or other events. For example, on Halloween the light may display lighting themes and color shows including, for example, flickering or washing oranges. On the Fourth of July, a red, white, and blue display may be provided. On December 25, green and red lighting may be displayed. Other themes may be provided for New Years, Valentine's Day, birthdays, etc. As another example, the device may provide different lighting effects at different times of day, or for different days of the week.

Figure 3 shows a glow stick according to the principles of the invention. The glow stick 15 may include the components described above with reference to Fig. 1, and may operate according to the techniques described above with reference to Figs. 2A-2B. The glow stick 15 may be any small, cylindrical device that may hang from a lanyard, string,

of LEDs within the spotlight 60, and may operate according to the techniques described above with reference to Figs. 2A-2B. The spotlight 60 may include a housing 65 suitable for use with convention lighting fixtures, such as those used with AC spotlights, and including a light-transmissive material on one end to permit LEDs to illuminate through the housing 65. The spotlight configurations may be provided to illuminate an object or for general illumination for example and the material may not be required. The mixing of the colors may take place in the projection of the beam for example. The spotlight 60 may draw power for illumination from an external power source through a connection 70, such as an Edison mount fixture, plug, bi-pin base, screw base, base, Edison base, spade plug, and power outlet plug or any other adapter for adapting the spotlight 60 to external power. The connection 70 may include a converter to convert received power to power that is useful for the spotlight. For example, the converter may include an AC to DC converter to convert one-hundred twenty Volts at sixty Hertz into a direct current at a voltage of, for example, five Volts or twelve Volts. The spotlight 60 may also be powered by one or more batteries 80, or a processor in the spotlight 60 may be powered by one or more batteries 80, with LEDs powered by electrical power received through the connection 70. A battery case 90 may be integrated into the spotlight 60 to contain the one or more batteries 80.

The connector 70 may include any one of a variety of adapters to adapt the spotlight 60 to a power source. The connector 70 may be adapted for, for example, a screw socket, socket, post socket, pin socket, spade socket, wall socket, or other interface. This may be useful for connecting the lighting device to AC power or DC power in existing or new installations. For example, a user may want to deploy the spotlight 60 in an existing one-hundred and ten VAC socket. By incorporating an interface to this style of socket into the spotlight 60, the user can easily screw the new lighting device into the socket. US Patent Application No. 09/213,537, entitled "Power/Data Protocol" describes techniques for

Figure 8 shows an Edison mount light bulb according to the principles of the invention. The light bulb 180 is similar to the light bulb 150 of Fig. 6, with a different user interface. The user interface of the light bulb 180 includes a thumbwheel 185 and a two-way switch 190. In this embodiment, the switch 190 may be used to move forward and backward through a sequence of available modes. For example, if the light bulb 180 has four modes numbered 1-4, by sliding the switch 190 to the left in Fig. 7, the mode may move up one mode, i.e., from mode 1 to mode 2. By sliding the switch 190 to the right in Fig. 7, the mode may move down one mode, i.e., from mode 2 to mode 1. The switch 190 may include one or more springs to return the switch 190 to a neutral position when force is not applied. The thumbwheel 185 may be constructed for endless rotation in a single direction, in which case a parameter controlled by the thumbwheel 185 may reset to a minimum value after reaching a maximum value (or vice versa). The thumbwheel may be constructed to have a predefined span, such as one and one-half rotations. In this latter case, one extreme of the span may represent a minimum parameter value and the other extreme of the span may represent a maximum parameter value. In an embodiment, the switch 190 may control a mode (left) and a parameter (right), and the thumbwheel 185 may control a brightness of the light bulb 180.

A light bulb such as the light bulb 180 of Fig. 7 may also be adapted to control through conventional lighting control systems. Many incandescent lighting systems have dimming control that is realized through changes in applied voltages, typically either through changes to applied voltages or chopping an AC waveform. A power converter can be used within the light bulb 180 to convert the received power, whether in the form of a variable amplitude AC signal or a chopped waveform, to the requisite power for the control circuitry and the LEDs, and where appropriate, to maintain a constant DC power supply for digital components. An analog-to-digital converter may be included to digitize the AC

three-way light bulb socket. The light bulb 180 could have two contacts on the base and a look-up table, a program, or other system within the light bulb 180 could contain control signals that correlate to the socket setting. Again, this could be used for illumination control, color control or any other desired control for the LEDs.

This system could be used to create various lighting effects in areas where standard lighting devices where previously used. The user can replace existing incandescent light bulbs with an LED lighting device as described herein, and a dimmer on a wall could be used to control color-changing effects within a room. Color changing effects may include dimming, any of the color-changing effects described above, or any other color-changing or static, colored effects.

Figure 9 shows a light bulb according to the principles of the invention. As seen in Fig. 8, the light bulb 200 may operate from fixtures other than Edison mount fixtures, such as an MR-16, low voltage fixture 210 that may be used with direct current power systems.

Figure 10 shows a wall socket mounted light according to the principles of the invention. The light 210 may include a plug adapted to, for example, a one-hundred and ten volt alternating current outlet 220 constructing according to ANSI specifications. The light 210 may include a switch and thumbwheel as a user interface 230, and one or more spades 240 adapted for insertion into the outlet 220. The body of the light 210 may include a reflective surface for directing light onto a wall for color changing wall washing effects.

Figure 11 shows a night light according to the principles of the invention. The night light 242 may include a plug 244 adapted to, for example, a one-hundred and ten volt alternating current outlet 246. The night light 242 may include a system such as that depicted in Fig. 1 for controlling a plurality of LEDs within the night light 242, and may operate according to the techniques described above with reference to Figs. 1B-1C. The

As will be appreciated from the foregoing examples, an LED system such as that described in reference to Figs. 1 & 2A-2B may be adapted to a variety of lighting applications, either as a replacement for conventional light bulbs, including incandescent light bulbs, halogen light bulbs, tungsten light bulbs, fluorescent light bulbs, and so forth, or as an integrated lighting fixture such as a desk lamp, vase, night light, lantern, paper lantern, designer night light, strip light, cove light, MR light, wall light, screw based light, lava lamp, orb, desk lamp, decorative lamp, string light, or camp light. The system may have applications to architectural lighting, including kitchen lighting, bathroom lighting, bedroom lighting, entertainment center lighting, pool and spa lighting, outdoor walkway lighting, patio lighting, building lighting, facade lighting, fish tank lighting, or lighting in other areas where light may be employed for aesthetic effect. The system could be used outdoors in sprinklers, lawn markers, pool floats, stair markers, in-ground markers, or door bells, or more generally for general lighting, ornamental lighting, and accent lighting in indoor or outdoor venues. The systems may also be deployed where functional lighting is desired, as in brake lights, dashboard lights, or other automotive and vehicle applications.

Color-changing lighting effects may be coordinated among a plurality of the lighting devices described herein. Coordinated effects may be achieved through conventional lighting control mechanisms where, for example, each one of a plurality of lighting devices is programmed to respond differently, or with different start times, to a power-on signal or dimmer control signal delivered through a conventional home or industrial lighting installation.

Each lighting device may instead be addressed individually through a wired or wireless network to control operation thereof. The LED lighting devices may have transceivers for communicating with a remote control device, or for communicating over a wired or wireless network.

by the at least one LED 1202. As with other examples, the lighting device 1200 may include a light-transmissive material 1212, a user interface 1214, and a plug 1216.

Figure 14 shows another embodiment of a wall washing light according to the principles of the invention. The night light 1300 may include an optic 1302 formed from a light-transmissive material and a detachable optic 1304. The detachable optic 1304 may fit over the optic 1302 in a removable and replaceable fashion, as indicated by an arrow 1306, to provide a lighting effect, which may include filtering, diffusing, focusing, and so forth. The detachable optic 1304 may direct illumination from the night light 1300 into a predetermined shape or image, or spread the spectrum of the illumination in a prismatic fashion. The detachable optic 1304 may, for example, have a pattern etched into including, for example, a saw tooth, slit, prism, grating, squares, triangles, half-tone screens, circles, semi-circles, stars or any other geometric pattern. The pattern can also be in the form of object patterns such as, but not limited to, trees, stars, moons, suns, clovers or any other object pattern. The detachable optic 1304 may also be a holographic lens. The detachable optic 1304 may also be an anamorphic lens configured to distort or reform an image. These patterns can also be formed such that the projected light forms a non-distorted pattern on a wall, provided the geometric relationship between the wall and the optic is known in advance. The pattern could be designed to compensate for the wall projection. Techniques for applying anamorphic lenses are described, for example, in "Anamorphic Art and Photography – Deliberate Distortions That Can Be Easily Undone," *Optics and Photonics News*, November 1992, the teachings of which are incorporated herein by reference. The detachable optic 1304 may include a multi-layered lens. At least one of the lenses in a multi-layered lens could also be adjustable to provide the user with adjustable illumination patterns.

rises the lighting device 1500 might project red illumination. The information is not limited to temperature information. The information could be any information that can be transmitted and received. Another example is financial information such as a stock price. When the stock price rises the projected illumination may turn green, and when the price drops the projected illumination may turn red. If the stock prices fall below a predetermined value, the lighting device 1500 may strobe red light or make other indicative effects.

It will be appreciated that systems such as those described above, which receive and interpret data, and generate responsive color-changing illumination effects, may have broad application in areas such as consumer electronics. For example, information be obtained, interpreted, and converted to informative lighting effects in devices such as a clock radio, a telephone, a cordless telephone, a facsimile machine, a boom box, a music box, a stereo, a compact disk player, a digital versatile disk player, an MP3 player, a cassette player, a digital tape player, a car stereo, a television, a home audio system, a home theater system, a surround sound system, a speaker, a camera, a digital camera, a video recorder, a digital video recorder, a computer, a personal digital assistant, a pager, a cellular phone, a computer mouse, a computer peripheral, or an overhead projector.

Figure 16 depicts a modular unit. A lighting device 1600 may contain one or more LEDs and a decorative portion of a lighting fixture. An interface box 1616 could contain a processor, memory, control circuitry, and a power supply to convert the AC to DC to operate the lighting device 1600. The interface box 1616 may have standard power wiring 1610 to be connected to a power connection 1608. The interface box 1616 can be designed to fit directly into a standard junction box 1602. The interface box 1616 could have physical connection devices 1612 to match connections on a backside 1604 of the lighting device 1600. The physical connection devices 1612 could be used to physically mount the

housing 1710. The light engine 1700 may be used in lighting fixtures or as a stand-alone device. The modular configuration may be amenable to use by lighting designers, architects, contractors, technicians, users or other people designing or installing lighting, who may provide predetermined data and power wiring throughout an installation, and locate a light engine 1700 at any convenient location therein..

Optics may be used to alter or enhance the performance of illumination devices. For example, reflectors may be used to redirect LED radiation, as described in US Patent Application No.60/235,966 "Optical Systems for Light Emitting Semiconductors," the teachings of which are incorporated herein by reference. US Patent Application No.60/235,966 is incorporated by reference herein.

Figure 18 shows a reflector that may be used with the systems described herein. As shown in Fig. 18, a contoured reflective surface 1802 may be placed apart from a plurality of LEDs 1804, such that radiation from the LEDs 1804 is directed toward the reflective surface 1802, as indicated by arrows 1806. In this configuration, radiation from the LEDs 1804 is redirected out in a circle about the reflective surface 1802. The reflective surface 1802 may have areas of imperfections or designs to create projection effects. The LEDs 1804 can be arranged to uniformly project the light onto the reflector or they can be arranged with a bias to increase the illumination on certain sections of the reflector. The individual LEDs 1804 of the plurality of LEDs 1804 can also be independently controlled. This technique can be used to create light patterns or color effects.

Figure 19 illustrates a reflector design where an LED 1900 is directed toward a generally parabolic reflector 1902, as indicated by an arrow 1903. The generally parabolic reflector 1902 may include a raised center portion 1904 to further focus or redirect radiation from the LED 1900. As shown by a second LED 1906, a second generally parabolic reflector 1908, and a second arrow 1910, the raised center portion 1904 may be omitted in

switch signals. This could be used, for example, to create a ball that has subtle effects when a single switch is activated, and dramatic effects when a plurality of switches are activated.

The ball may respond to transducer signals. For example, one or more velocity or acceleration transducers could detect motion in the ball. Using these transducers, the ball may be programmed to change lighting effects as it spins faster or slower. The ball could also be programmed to produce different lighting effects in response to a varying amount of applied force. There are many other useful transducers, and methods of employing them in a color-changing ball.

The ball may include a transceiver. The ball may generate color-changing effects in response to data received through the transceiver, or may provide control or status information to a network or other devices using the transceiver. Using the transceiver, the ball may be used in a game where several balls communicate with each other, where the ball communicates with other devices, or communicates with a network. The ball could then initiate these other devices or network signals for further control.

A method of playing a game could be defined where the play does not begin until the ball is lighted or lighted to a particular color. The lighting signal could be produced from outside of the playing area by communicating through the transceiver, and play could stop when the ball changes colors or is turned off through similar signals. When the ball passes through a goal the ball could change colors or flash or make other lighting effects. Many other games or effects during a game may be generated where the ball changes color when it moves too fast or it stops. Color-changing effects for play may respond to signals received by the transceiver, respond to switches and/or transducers in the ball, or some combination of these. The game hot potato could be played where the ball continually changes colors, uninterrupted or interrupted by external signals, and when it suddenly or gradually changes to red or some other predefined color you have to throw the ball to

mount LED's may be secured directly to the body 2200 on an interior surface of a diffusing material.

The input/output 2210 may include an input device such as a button, dial, slider, switch or any other device described above for providing input signals to the device 2200, or the input/output 2210 may include an interface to a wired connection such as a Universal Serial Bus connection, serial connection, or any other wired connection, or the input/output 2210 may include a transceiver for wireless connections such as infrared or radio frequency transceivers. In an embodiment, the wearable accessory may be configured to communicate with other wearable accessories through the input/output 2210 to produce synchronized lighting effects among a number of accessories. For wireless transmission, the input/output 2210 may communicate with a base transmitter using, for example, infrared or microwave signals to transmit a DMX or similar communication signal. The autonomous accessory would then receive this signal and apply the information in the signal to alter the lighting effect so that the lighting effect could be controlled from the base transmitter location. Using this technique, several accessories may be synchronized from the base transmitter. Information could also then be conveyed between accessories relating to changes of lighting effects. In one instantiation, the input/output 2210 may include a transmitter such as an Abacom TXM series device, which is small and low power and uses the 400Mhz spectrum. Using such a network, multiple accessories on different people, can be synchronized to provide interesting effects including colors bouncing from person to person or simultaneous and synchronized effects across several people. A number of accessories on the same person may also be synchronized to provide coordinated color-changing effects. A system according to the principle of the invention may be controlled though a network as described herein. The network may be a personal, local, wide area or

housing 2302, one or more of the components may be included within the first housing 2302.

Figure 24 depicts an autonomous color-changing shoe according to the principles of the invention. A shoe 2400 includes a main portion 2402, a heel 2404, a toe 2406, and a sole 2408. The main portion 2402 is adapted to receive a human foot, and may be fashioned of any material suitable for use in a shoe. The heel 2402 may be formed of a translucent, diffusing material, and may have embedded therein a system such as that described with reference to Figs. 1 and 2A-2B. In addition to, or instead of a heel 2402 with autonomous color changing ability, another portion of the shoe 2400 may include an autonomous color changing system, such as the toe 2406, the sole 2408, or any other portion. A pair of shoes may be provided, each including an input/output system so that the two shoes may communicate with one another to achieve synchronized color changing effects. In an embodiment of the shoe 2400, circuitry may be placed within a sole 2408 of the shoe, with wires for driving LED's that are located within the heel 2404 or the toe 2406, or both.

As will be appreciated from the foregoing example, the systems disclosed herein may have wide application to a variety of wearable and ornamental objects. Apparel employing the systems may include coats, shirts, pants, clothing, shoes, footwear, athletic wear, accessories, jewelry, backpacks, dresses, hats, bracelets, umbrellas, pet collars, luggage, and luggage tags. Ornamental objects employing the systems disclosed herein may include picture frames, paper weights, gift cards, bows, and gift packages.

Color-changing badges and other apparel may have particular effect in certain environments. The badge, for example, can be provided with a translucent, semi-translucent or other material and one or more LEDs can be arranged to provide illumination of the material. In a one embodiment, the badge would contain at least one red, one blue

a semi-translucent material, a transparent material, plastic, paper, glass, ice, a frozen liquid or any other material suitable for forming into an icicle and propagating LED radiation. The icicle 2604 may be hollow, or may be a solid formed from light-transmissive material. The illumination from the lighting device 2602 is directed at the icicle 2604 and couples with the icicle 2604. The icicle material may have imperfections to provide various lighting effects. One such effect is created when a primarily transparent material contains a pattern of defects. The defects may redirect the light passing through or along the material, causing bright spots or areas to appear in the illuminated material. If these imperfections are set in a pattern, the pattern will appear bright while the other areas will not appear lighted. The imperfections can also substantially cover the surface of the icicle 2604 to produce a frosted appearance. Imperfections that substantially uniformly cover the surface of the icicle 2604 may create an effect of a uniformly illuminated icicle.

The icicle 2604 can be lit with one or more LEDs to provide illumination. Where one LED is used, the icicle 2604 may be lit with a single color with varying intensity or the intensity may be fixed. In one embodiment, the lighted icicle 2600 includes more than one LED and in another embodiment the LEDs are different colors. By providing a lighted icicle 2600 with different colored LEDs, the hue, saturation and brightness of the lighted icicle 2600 can be changed. The two or more LEDs can be used to provide additive color. If two LEDs were used in the lighted icicle 2600 with circuitry to turn each color on or off, four colors could be produced including black when neither LED is energized. Where three LEDs are used in the lighted icicle 2600 and each LED has three intensity settings, 3^3 or 27 color selections are available. In one embodiment, the LED control signals would be PWM signals with eight bits (=128 combinations) of resolution. Using three different colored LEDs, this provides 128^3 or 16.7 million available colors.

cycling through programs or modes of operation are known, and may be suitably adapted to the systems described herein.

Figure 28 depicts an icicle 2800 having a flange 2802. The flange 2802 may allow easy mounting of the icicle 2800. In one embodiment, the flange 2802 is used such that the flange couples with a ledge 2808 while the remaining portion of the icicle 2800 hangs through a hole formed by the ledge 2808. This method of attachment is useful where the icicles can hang through existing holes or holes can be made in the area where the icicles 2800 are to be displayed. Other attachment methods are known, and may be adapted to use with the invention.

Figure 29 shows an icicle according to the principles of the invention. A plurality of LEDs 2900 may be disposed in a ring 2902. The ring 2902 may be engaged to a flange 2904 of an icicle 2906. Arranged in this manner, the LEDs 2900 may radiate illumination that is transmitted through icicle 2906. If the ring 2902 is shaped and sized so that the LEDs 2900 directly couple to the flange 2904, then the icicle 2906 will be edge-lit. The ring 2902 may instead be smaller in diameter than the flange 2904, so that the LEDs 2900 radiate into a hollow cavity 2908 in the icicle 2906, or onto a top surface of the icicle 2906 if the icicle 2906 is formed of a solid material.

Figure 30 depicts a solid icicle 3000 which may be in the form or a rod or any other suitable form, with one or more LEDs 3002 positioned to project light into the solid icicle 3000.

Figure 31 depicts a rope light according to the principles of the invention. The rope light 3100 may include a plurality of LEDs or LED subsystems 3102 according to the description provided in reference to Figs. 1 and 2A-2B. In one embodiment, three LED dies of different colors may be packaged together in each LED subsystem 3102, with each die individually controllable. A plurality of these LED subsystems 3102 may be disposed

Claims

We Claim:

1. A device comprising:

a plurality of LEDs that produce at least two different spectra;

a material configured to receive light emitted from the plurality of LEDs, and to display a color that is a combination of the spectra of the plurality of LEDs;

a processor, the processor generating a control signal, the control signal changing over time to produce from the consumer product a color-changing effect; and

a controller that receives the control signal, the controller controlling power delivered to one or more of the plurality of LEDs in response to the control signal; and

a user interface adapted to receive a user input to control operation of the processor.

2. The device of claim 1 wherein the processor operates in one of a plurality of modes, each mode producing a lighting effect according to one or more parameters.

3. The device of claim 1 wherein the user interface consists of a single button.

4. The device of claim 1 wherein the user interface consists of two buttons.

5. The device of claim 1 wherein the user interface includes an adjustable input.

6. The device of claim 1 wherein the user interface includes at least one of a button, a dial, a slider, a knob, or a keypad.

7. The device of claim 1 wherein the color-changing effect includes at least one of a color wash, a strobe, a fade, or a Holiday lighting effect.

8. The device of claim 1 wherein the device comprises a consumer product.

9. A lighting system comprising:

16. A lighting system of claim 11 further comprising a housing wherein the LEDs, processor, memory, and controllers are substantially enclosed by the housing, and wherein the user interface is associated with the housing and the light-transmissive material is associated with the housing.

17. A lighting system of claim 11 further comprising:

a housing wherein the housing substantially encloses the processor, memory, and controllers;

a second housing wherein the second housing substantially encloses the at least two LEDs; and

the light-transmissive material is associated with the second housing.

18. A lighting system of claim 9 wherein the light-transmissive material comprises at least one of a semitransparent material, translucent material, semitransparent material and transparent material.

19. A lighting system of claim 9 wherein the at least two controllers are at least one of a pulse width modulator, pulse amplitude modulator, pulse displacement modulator, resistor ladder, current source, voltage source, voltage ladder, switch, transistor, and voltage controller.

20. A lighting system of claim 11 wherein the user interface comprises an encoder wherein the encoder provides an encoder signal; the processor changes at least one of a program and program parameter upon receipt of the encoder signal.

21. A lighting system of claim 20 wherein the user interface further comprises at least one of a dial, button, switch, slider, variable switch, and variable selector.

22. A lighting system of claim 12 or 13 wherein the user interface further comprises at least one of a button and switch.

23. A lighting system of claim 10 further comprising:

an analog to digital converter;

29. A lighting system of claim 28 wherein the user interface supplies at least one of a logic high signal and logic low signal to the processor wherein the processor selects a program from the memory upon receipt of a user interface signal.

30. A lighting system of claim 28 wherein the user interface supplies at least one of a logic high signal and logic low signal to the processor wherein the processor adjusts a program parameter upon receipt of a user interface signal.

31. A lighting system of claim 29 wherein the processor further comprises a timer; the timer measures the duration of the user interface signal and the processor adjusts a parameter of the program upon receipt of a predetermined duration of the user interface signal.

32. A lighting system of claim 31 wherein the parameter continues to change until the user interface signal changes.

33. A lighting system of claim 28 further comprising:

a housing wherein the LEDs, processor, memory, and controllers are substantially enclosed by the housing;

the user interface is associated with the housing; and

the light-transmissive material is associated with the housing.

34. A lighting system of claim 26 wherein the at least two controllers comprise at least one of a pulse width modulator, pulse amplitude modulator, pulse displacement modulator, resistor ladder, voltage ladder, current source, voltage source, switch, transistor, and voltage controller.

35. A lighting system of claim 28 wherein the user interface is an encoder wherein the encoder provides an encoder signal; the processor changes at least one of a program and program parameter upon receipt of the encoder signal.

36. A lighting system of claim 35 wherein the user interface further comprises at least one of a dial, button, switch, slider, variable switch, and variable selector.

an energy storage element wherein the energy storage element is associated with a power source;

the energy storage element communicates at least one of a high logic signal and a low logic signal to the processor;

wherein a logic is formed when the logic signal changes from its original state to a second state and then back to the original state;

wherein the processor selects a program from the memory upon receipt of a logic cycle within a predetermined period of time.

47. A lighting system of claim 46 wherein the energy storage element is at least one of a capacitor, non-volatile memory, relay, and storage device.

48. A lighting system of claim 46 further comprising:

a last program wherein the last program comprises the program that was active prior to de-energizing the lighting system;

wherein the memory is at least one of non-volatile memory, and battery backed memory;

wherein the processor selects the last program upon re-energizing the lighting system after a predetermined period of time.

49. A lighting system of claim 26 wherein the light-transmissive material is a lens, secondary optic, holographic lens, anamorphic lens, and patterned lens.

50. A lighting system of claim of 10 or 27 wherein the user interface is remotely located from the processor.

51. A lighting system of claim 50 wherein the communication from the user interface to the processor is accomplished through at least one of an electromagnetic transmission, radio frequency transmission, infrared transmission, microwave transmission, acoustic transmission, wire transmission, cable transmission, and network transmission.

52. An ornamental lighting system comprising:

at least two LEDs wherein the at least two LEDs produce at least two different spectra;

a processor;

a power converter wherein the power converter converts the power from a power supply into power for at least one of the processor and LEDs;

at least two controllers wherein the controllers independently control power delivered to the at least two LEDs;

the at least two controllers further comprising a signal input wherein the signal input is associated with the processor;

the at least two controllers are responsive to signals communicated to the signal input; and

a light-transmissive material wherein the LEDs are arranged to illuminate the light-transmissive material.

55. A nightlight of claim 54 further comprising:

a user interface wherein the user interface is associated with the processor; and

memory wherein the memory is associated with the processor.

56. A nightlight of claim 54 wherein the LED produce illumination wherein the illumination is projected from the nightlight onto a wall.

57. A nightlight of claim 54 further comprising a second transmissive material wherein the second transmissive material is detachably connected to the night light.

58. A nightlight of claim 57 wherein the second transmissive material is at least one of a lens, secondary optic, holographic lens, anamorphic lens, and patterned lens.

59. A nightlight of claim 54 further comprising:

memory wherein the memory is associated with the processor;

an energy storage element wherein the energy storage element is associated with a power source;

the energy storage element communicates at least one of a high logic signal and a low logic signal to the processor;

the LEDs are arranged to illuminate the portion of light-transmissive material.

63. A lighted ball of claims 61 or 62 further comprising:

a switch associated with the processor wherein the switch comprises at least one of a hall effect switch, motion sensing switch, proximity detector, sensor, transducer, capacitive switch, and inductive switch.

64. A lighted ball of claims 61 or 62 further comprising:

a receiver for receiving at least one of a electromagnetic transmission, radio frequency transmission, infrared transmission, microwave transmission, acoustic transmission, network transmission, wire transmission, and cable transmission; wherein the receiver is associated with the processor.

65. A lighted ball of claims 61 or 62 further comprising:

an analog to digital converter wherein the analog to digital converter communicates a digital signal to the processor;

a receiver for receiving at least one of a electromagnetic transmission, radio frequency transmission, infrared transmission, microwave transmission, acoustic transmission, network transmission, wire transmission, and cable transmission; wherein the receiver communicates an analog signal to the analog to digital converter.

66. A wearable accessory comprising:

at least two LEDs wherein the at least two LEDs produce at least two different spectra;

a processor;

at least two controllers wherein the controllers independently control power delivered to the at least two LEDs;

the at least two controllers further comprising a signal input wherein the signal input is associated with the processor;

the at least two controllers are responsive to signals communicated to the signal input;

a housing wherein the housing substantially encloses at least one of the at least two LEDs, processor, and controllers;

an analog to digital converter wherein the analog to digital converter is communicates a digital signal to the processor;

a receiver for receiving at least one of a electromagnetic transmission, radio frequency transmission, infrared transmission, microwave transmission, acoustic transmission, network transmission, wire transmission, and cable transmission; wherein the receiver communicates an analog signal to the analog to digital converter.

75. A lighting system of claim 26, 53 or 54 wherein the power converter further comprising a power supply connection; the power connection comprises at least one of a plug, bi-pin base, screw base, base, Edison base, Edison mount spade plug, and power outlet plug.

76. A digital light engine comprising:

at least one LED;

a processor;

at least one controller wherein the controller controls power delivered to the at least one LED;

the at least one controller further comprising a signal input wherein the signal input is associated with the processor;

the at least one controller being responsive to signals communicated to the power signal input;

a housing that encloses the processor and the controller, the at least one LED attached to the housing;

77. A digital light engine of claim 76 wherein the external input connection comprises at least one receiver wherein the receiver is capable of receiving transmissions of at least one of electromagnetic transmissions, radio frequency transmissions, infrared transmissions, microwave transmissions, acoustic transmissions, wire transmissions, cable transmissions and network transmissions.

78. A digital light engine of claim 76 wherein the external input connection is a user interface.

84. A digital light engine of claim 82 wherein the external input connection is a user interface.

85. A digital light engine of claim 84 wherein the user interface is at least one of a button, dial, slider, linear switch, rotary switch, and encoder switch.

86. A digital light engine of claim of 82 wherein the processor is at least one of a controller, addressable controller, microprocessor, microcontroller, addressable microprocessor, computer, programmable processor, programmable controller, dedicated processor, dedicated controller, and integrated circuit.

87. A digital light engine comprising:

at least two LEDs wherein the at least two LEDs produce different spectra;

a processor;

at least two controllers wherein the at least two controllers control power delivered to the at least two LEDs;

the at least two controllers further comprising a signal input wherein the signal input is associated with the processor;

the at least two controllers are responsive to signals communicated to the signal input;

a power converter wherein the power converter converts the power from a power supply into power for at least one of the processor and LEDs;

a platform wherein the at least one LED, processor, and the at least one controller are associated with the platform; and

an external input connection wherein the external input connection is associated with the processor.

88. A digital light engine of claim 87 wherein the external input connection comprises at least one receiver wherein the receiver is capable of receiving transmissions of at least one of electromagnetic transmissions, radio frequency transmissions, infrared transmissions, microwave transmissions, acoustic transmissions, wire transmissions, cable transmissions and network transmissions.

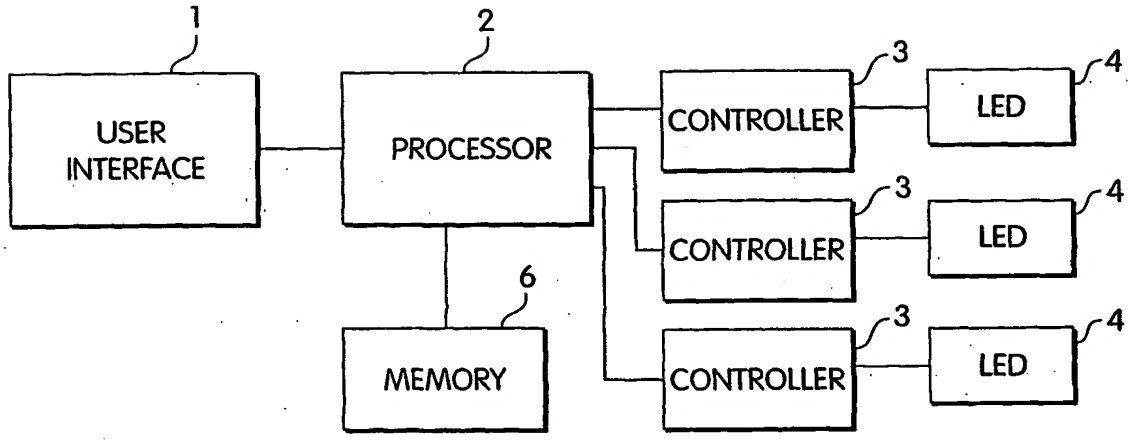

Fig. 1

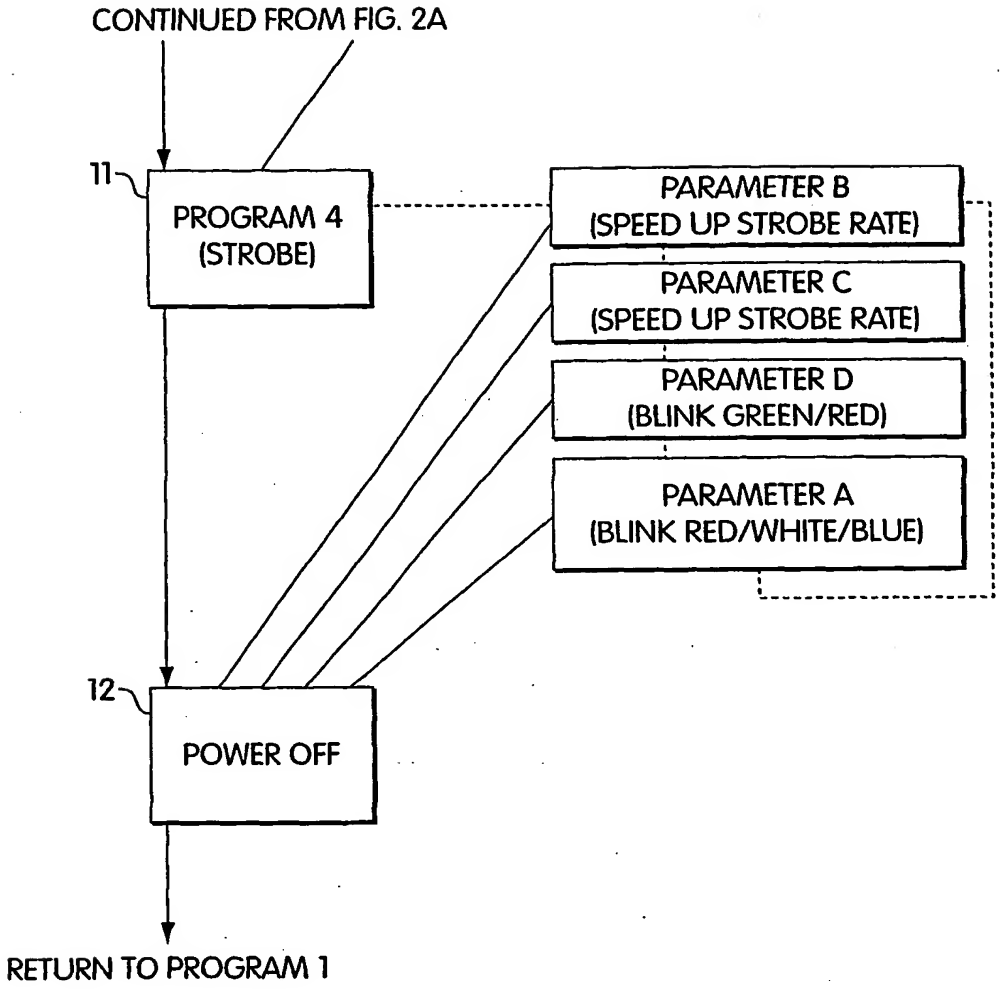

Fig. 2B

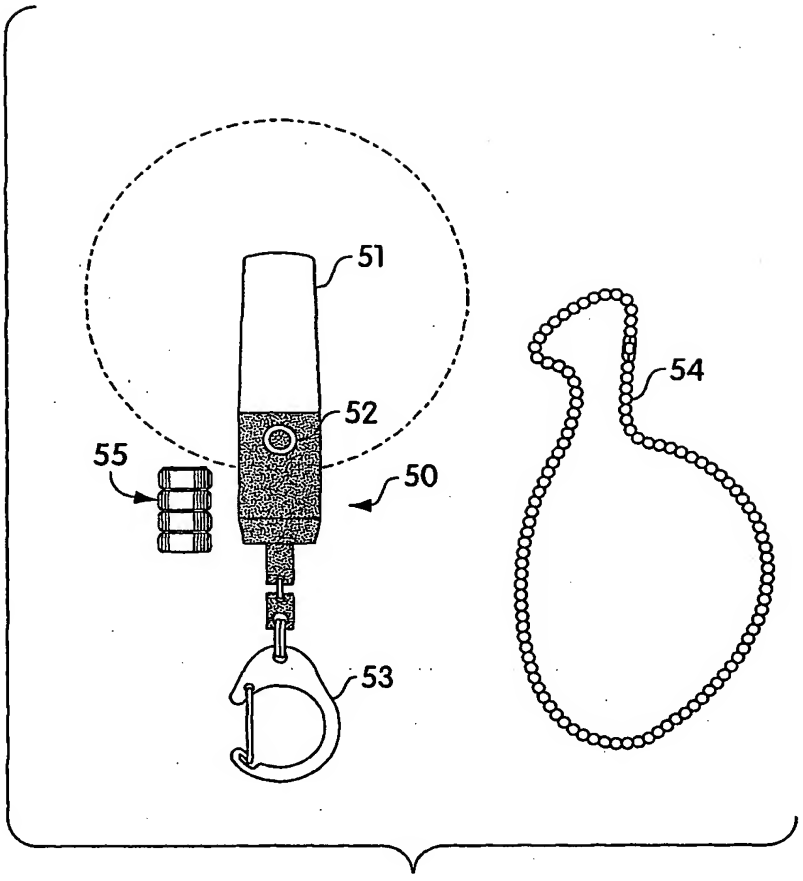

Fig. 4

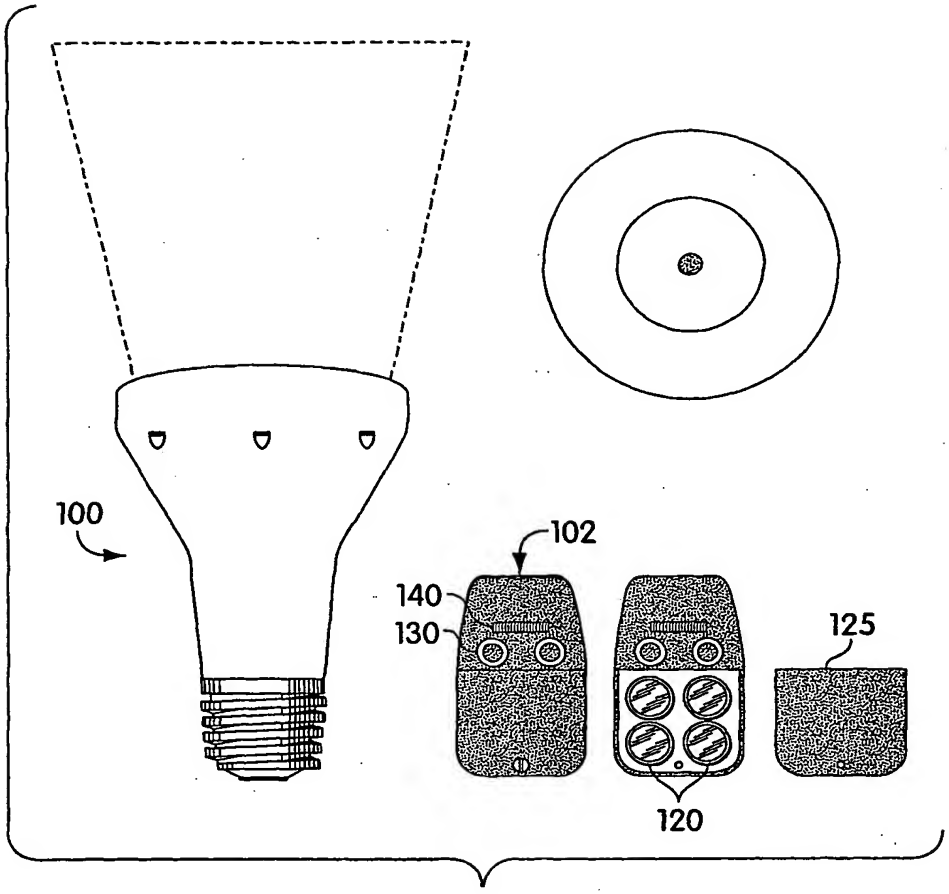

Fig. 6

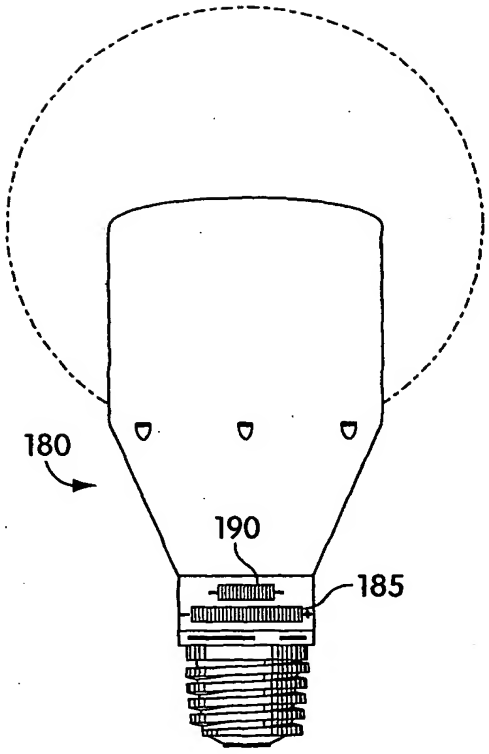

Fig. 8

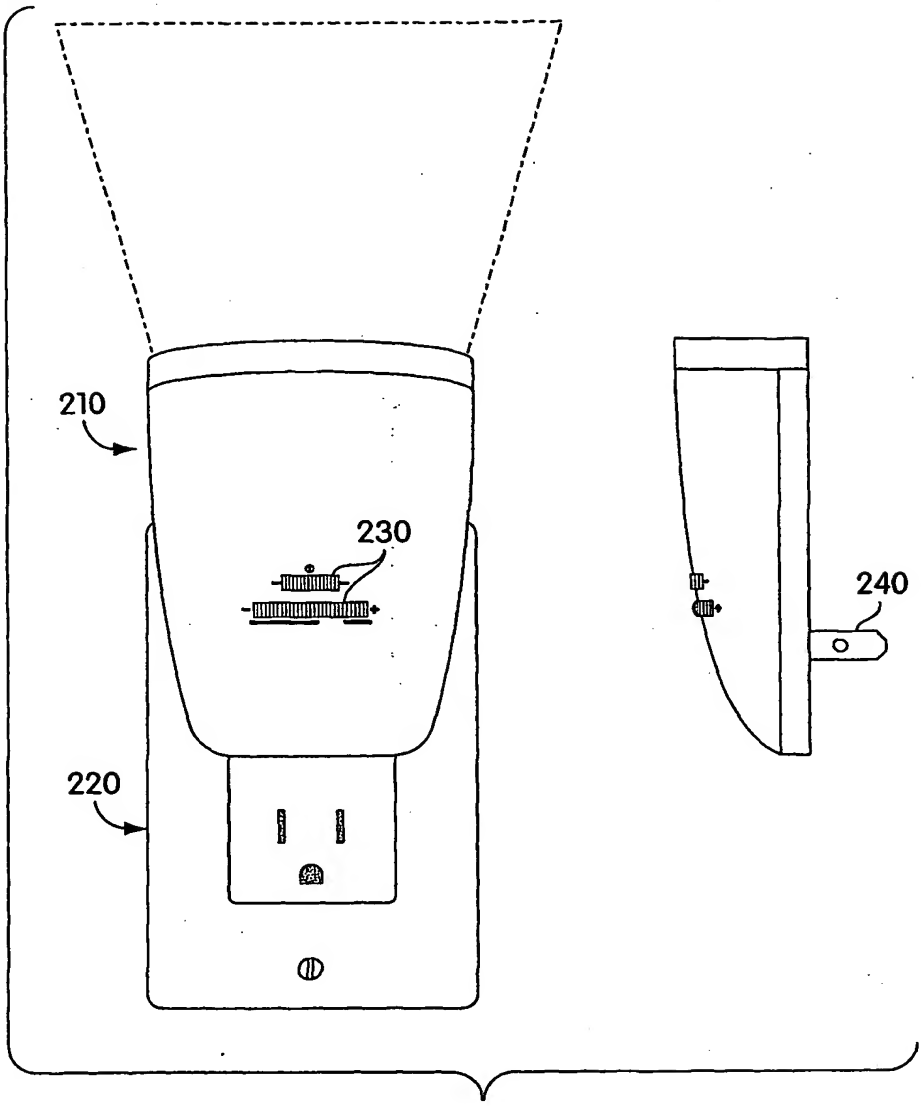

Fig. 10

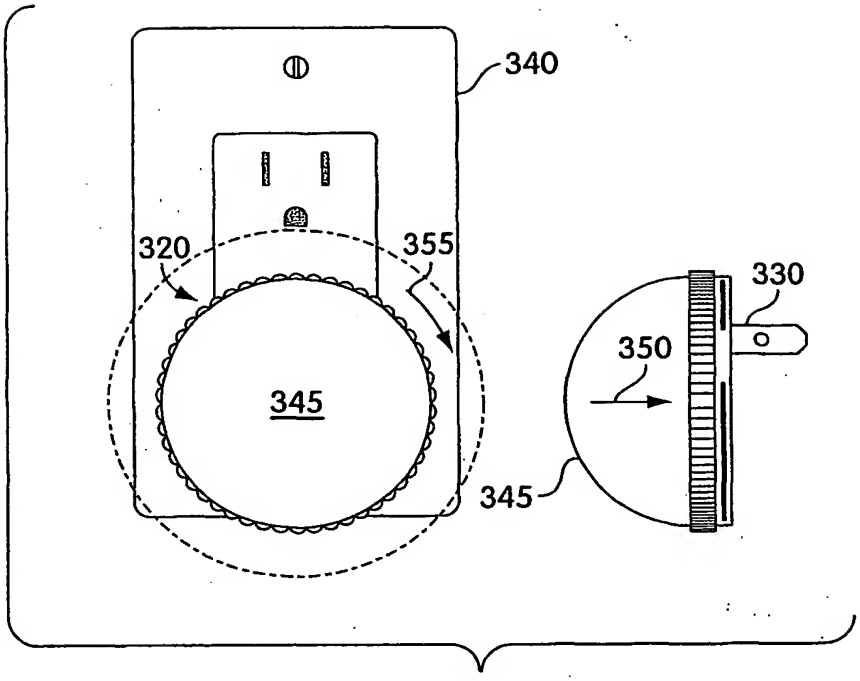

Fig. 12

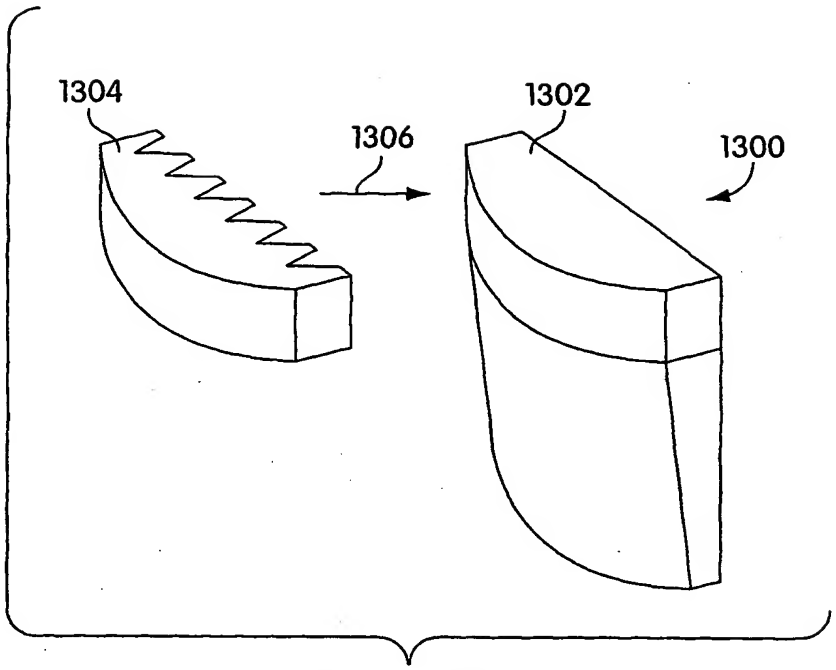

Fig. 14

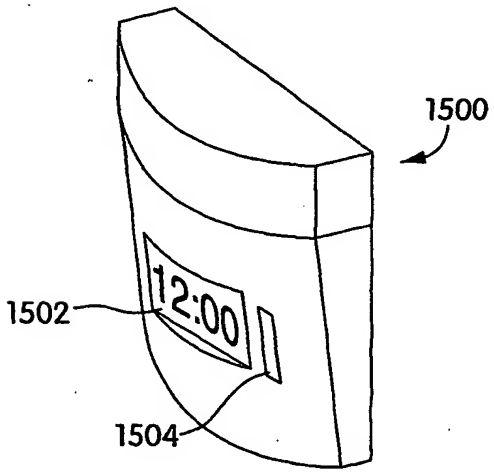

Fig. 15

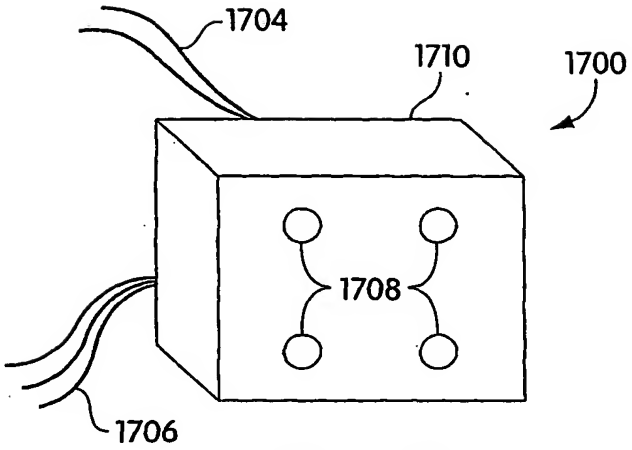

Fig. 17

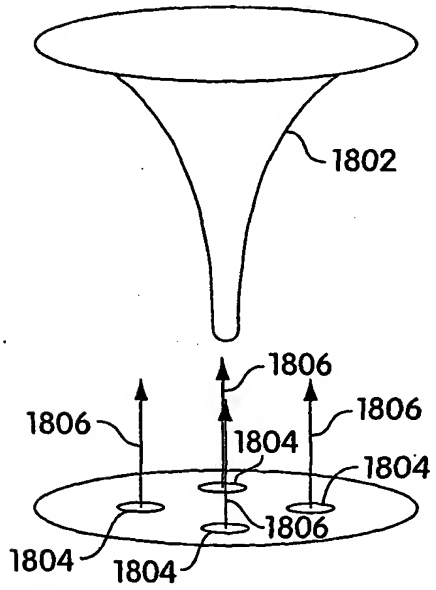

Fig. 18

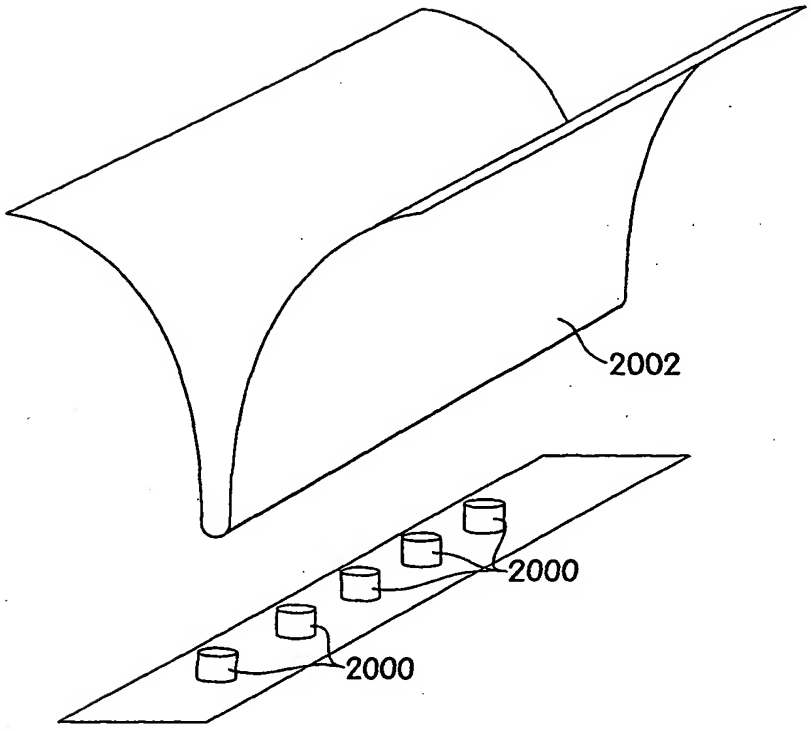

Fig. 20

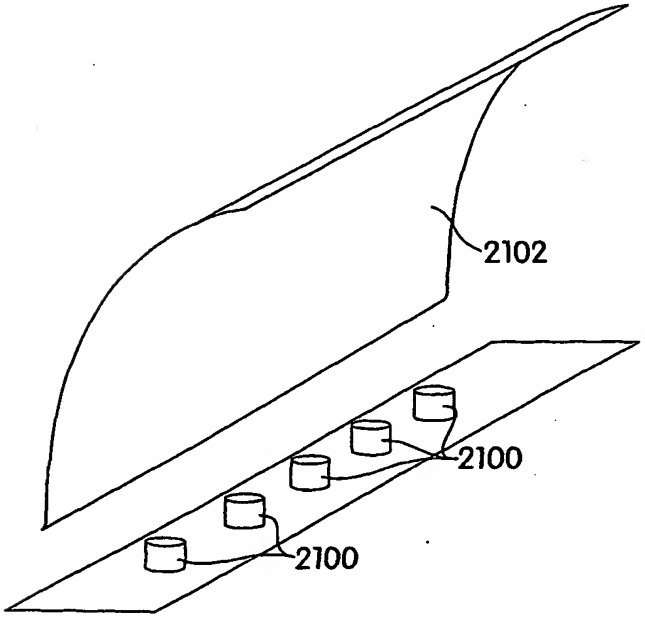

Fig. 21

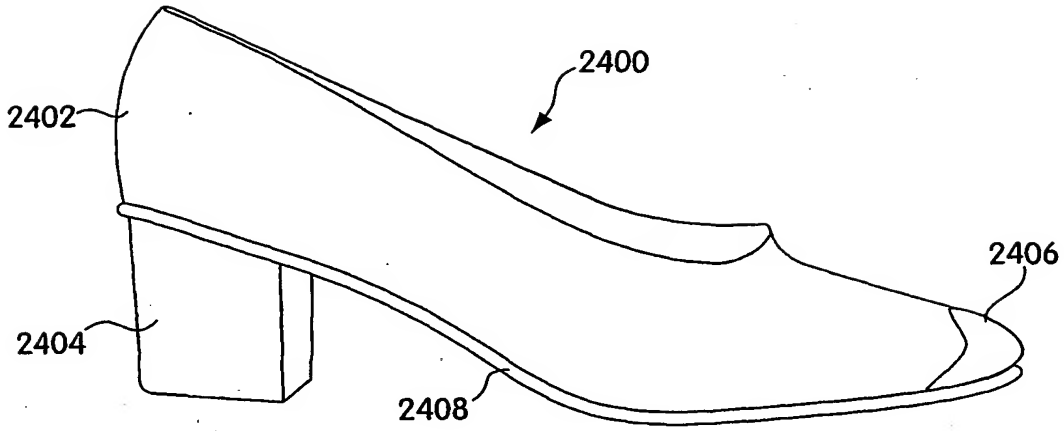

Fig. 24

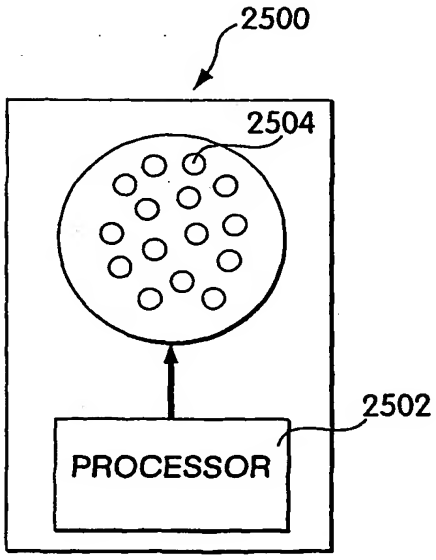

Fig. 25

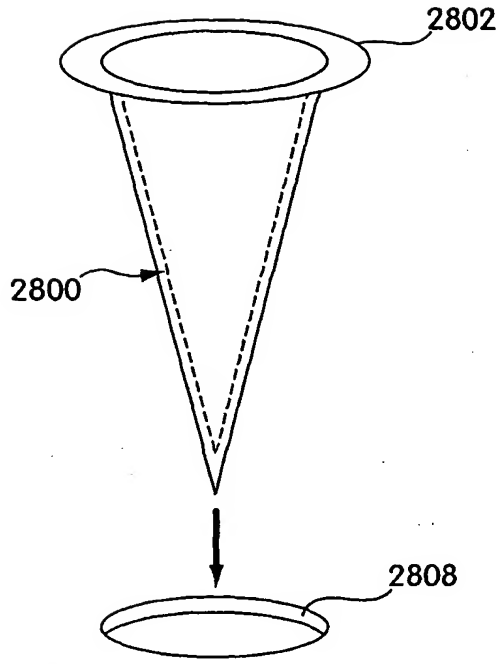

Fig. 28

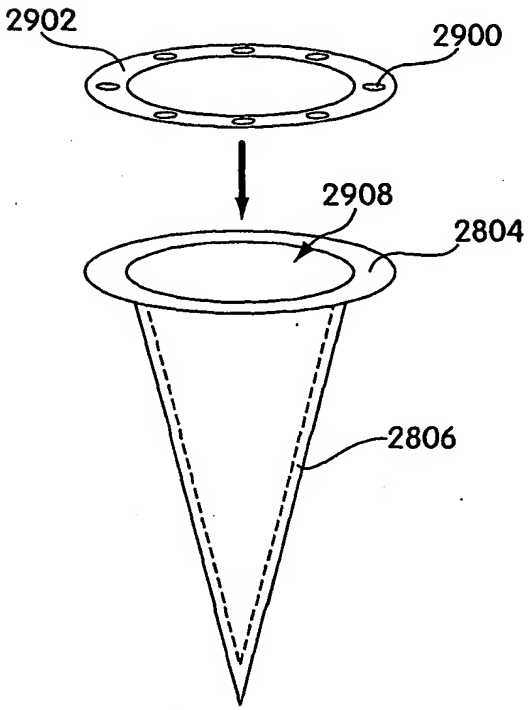

Fig. 29

INTERNATIONAL SEARCH REPORT

Int ional Application No
PCT/US 01/13151

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05B33/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 016 038 A (LYS IHOR A ET AL) 18 January 2000 (2000-01-18) the whole document ---	1-42,46, 49-51, 72-74, 76-91
X	US 3 737 647 A (GOMI Y) 5 June 1973 (1973-06-05) the whole document --- -/--	1-3,7-9, 18,52, 66, 68-71, 76-79, 81,82,87

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 August 2001	05/09/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Maicas, J.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

nformation on patent family members

Int ional Application No
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